



Could the footprint belong to the person in the image?

Overview

In this classroom activity you are to prepare a report for Belinda, the manager of a forensic science unit. Your report may be used as evidence by crime investigators so it must be clear and easy to understand. A part image of a person from a security camera and a footprint are the two key pieces of evidence from the crime scene. Are they from the same person?

Instructions

You, Dan and Lucy work in a forensic science unit lead by Belinda. The unit is asked to investigate whether a footprint, found at a crime scene, belongs to the person whose partial image is captured by a security camera at the scene.

The footprint was measured to be 24 cm in length.

These pieces of evidence are all that the team has to work on.



Task One: Dan's first thoughts

Dan suggests that if they can determine the true belly-button height of the man in the image from the security camera they may be able to make some progress.

After some investigation Dan identifies the brand and style of the board shorts being worn by the person. He also finds that they are made as a "one size fits all" with a length of 56 cm. Could this be used to find the real-life belly button height?

- 1.** With a partner list as many ways as you can to estimate the real-life belly-button height of the person in the image.

Answers will vary but might include in increasing level of sophistication:

(i) Using estimation. By observation, students may see that the shorts look a little more than half of the bellybutton height and estimate the bellybutton height to be a bit less than double the shorts length.

(ii) Using a scale. Unitary method: if 8cm in the photo represents 56 cm then 1 cm will represent 7cm. Measure the bellybutton height in the photo and multiply by 7.

(iii) Measure the height of the belly button and shorts in the photo. Compare this to actual measurement of shorts of 56 cm. Let x represent actual bb height.

	<i>Belly button(cm)</i>	<i>Shorts(cm)</i>
<i>Length in photo</i>	<i>14</i>	<i>8</i>
<i>Actual height</i>	<i>x</i>	<i>56</i>

Solve as a ratio: $\frac{x}{14} = \frac{56}{8}$

*Teacher note: A sound understanding of multiplicative thinking is essential here. When we measure the image height of the belly button it is found to be longer than the length of the shorts. Eg belly button height 14.1 cm compared to shorts 8 cm. Level of accuracy can be selected according to age of the class. For Year 5 this could be simplified to 14cm and 8 cm. This means that the bellybutton height is 14 cm compared with the shorts length of 8cm. **How many times** longer 14 is than 8 will tell us how many times taller belly button height is than 56cm.*

- 2.** Choose one way and use it to estimate the belly-button height of the person in the image. Don't forget to include any rules, tables or graphs you used.

Using each of the methods above:

(i) Shorts are 56cm so belly button height will be a little less than 2 times 56cm. So a little less than 112cm - estimate 100cm.

(ii) 1 cm in the image represents 7 cm of actual height. If bellybutton image is 14 cm then real height will be $14 \times 7 = 98\text{cm}$.

(iii) $\frac{x}{14} = \frac{56}{8}$

$$x = \frac{56}{8} \times 14$$

$$= 98 \text{ cm}$$

Task Two: Lucy poses a question

Is it possible to estimate the height of a person from their 'belly-button' height?

Height and belly button height are measured in the CensusAtSchool questionnaire. This data could be used to investigate Lucy's question.

- 3.** Brainstorm ideas of how you can investigate Lucy's question using the CensusAtSchool data.

Again suggestions are in increasing level of sophistication:

(i) *Find someone, preferably a male, who has the same belly-button height and then use the corresponding height.*

(ii) *Find several males with the same belly button height and then calculate the mean height of these males.*

(iii) *Construct a scatterplot of height vs belly-button height and use a line of best fit by eye to read the height for the given belly-button height.*

(iv) *Construct a scatterplot of height vs belly-button height and use a line of best fit by eye to calculate the equation of the line. Use substitution to estimate the height for the given belly-button height.*

- 4.** Choose one way and use it to estimate the height of the person in the image. Don't forget to include any rules, tables or graphs you used.

You can use a [prepared random sample](#) Excel spreadsheet or you can go to the CensusAtSchool website and use [the Random Sampler](#) to obtain your own sample.

Reference year	2008
Select questions	All (or Only those common to 2006 and 2008*)
Sample size	200

*This option is a simpler database as it has the answers to fewer questions. Ensure you use the sheet labelled 2008.

Answers are provided for each of the methods above using a random sample

Method (i) As luck would have it, in the sample, no student had a belly-button height of 98cm. Interesting discussion can be had around solving this mini problem. As this is the simplest approach we could assume that students using this method may be using the estimate of 100cm belly button height. The first

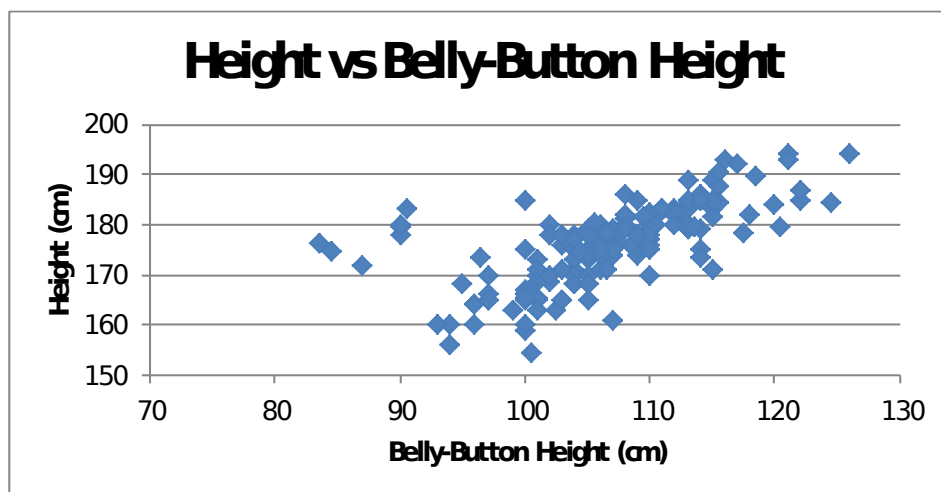
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person with a belly-button height of 100 cm has a height of 166cm.

Method (ii) As there are no students of 98cm find the mean height of students who had a belly-button height of 97 and 99 cm. However there is only 1 student with a height of 99cm and there are 4 with a height of 97cm. This would clearly lead to an inflated estimate of the mean height for a student with a belly button height of 98cm. One way around this could be to take the mean of the 4 students and then find the halfway point (in this case the mean) between this mean and the height of the single student. Following this the estimate for the height of the male with a 98cm belly-button is 165cm.

Method (iii) In this scatterplot Height(yaxis) will depend on the belly-button height (xaxis)The first scatterplot of the data shows a number of outliers. A decision needs to be made about whether to retain or delete these values. Whether due to error or extreme values, for accuracy, it is better to delete them. For this sample any pairs with a height less than 100cm or a belly-button height lower than 60cm or above 150cm were deleted. After this the reasonableness of other entries eg (70,187) can also be questioned and deleted if necessary.



Reading from the line of best fit we can predict that the height of a man with a belly-button height of 98cm will be 162 cm.

Method (iv)The equation of the trendline is:

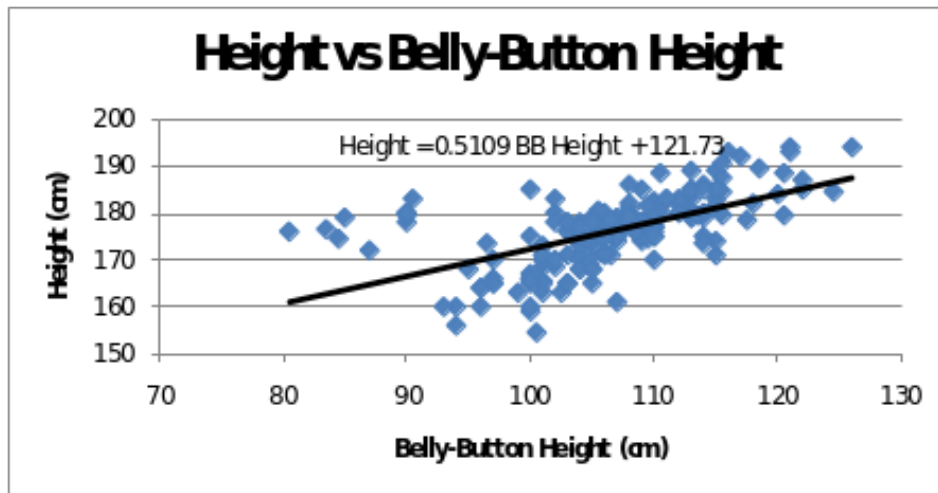
$$\text{Height} = 0.5199 \times \text{Belly-Button Height} + 121.73$$

Therefore we can substitute in the value of 98 cm for BB Height to find:

$$\text{Height} = 0.5199 \times 98 + 121.73$$

$$= 172.68 \text{ cm}$$

$$= 172.5 \text{ cm rounded to required level of accuracy}$$



Teacher Note: it is worth mentioning the influence of the first 8 data points above the trend line. Without these it is probable that the gradient of the line would be steeper and the predicted value of height would be lower. It could be said therefore that the predicted height is at the lower end of the expected height of this person. There are many interesting questions that can be posed around this that can lead to the assumptions just mentioned.

Task Three: Another thought

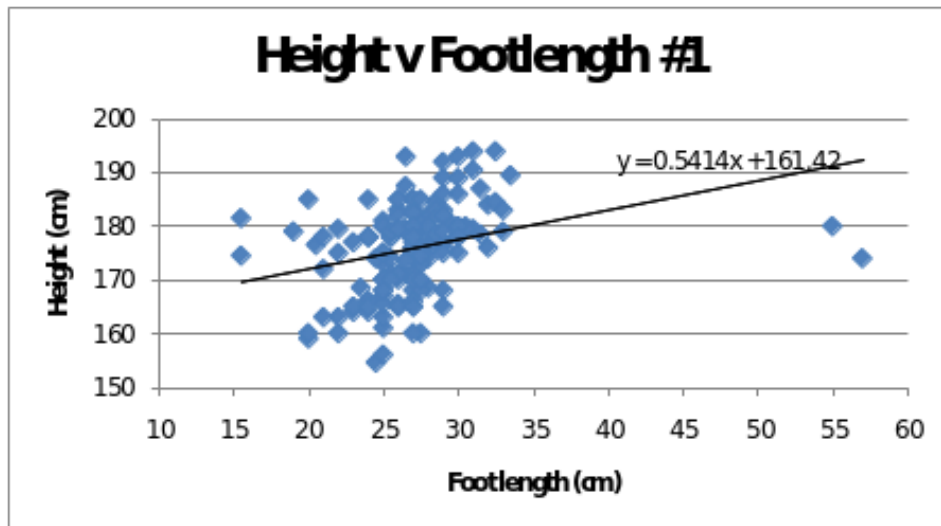
Can the sample be used to estimate the height of a person from the length of their foot? If you can, is it the same as the height from the belly button estimation?

- 5.** Brainstorm ideas of how you could investigate if it is possible to estimate the height of a person from the length of their foot.

Similar answers as question 4 above.

- 6.** Choose one way and use it to estimate the height of the person who left the footprint. Don't forget to include any rules, tables or graphs you used.

Using the linear trendline method. Even though the Guinness Book of Records lists the longest foot length as 68.58cm all foot lengths greater than 60 cm were eliminated since they appear as outliers in the scatterplot Likewise foot lengths 12 cm and lower were also eliminated.



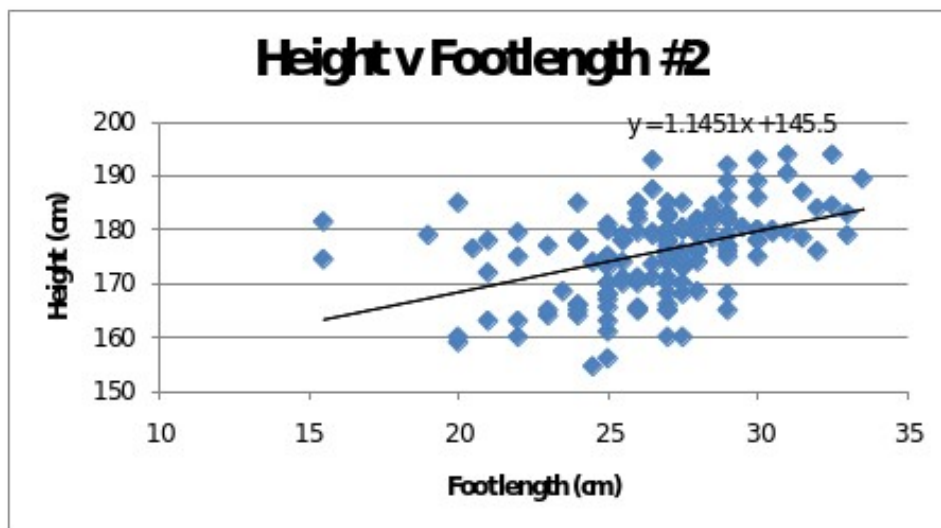
Using the relationship $\text{Height} = 0.5414 \times \text{Foot length} + 161.42$, the height of the suspect would be calculated $\text{Height} = 0.5414 \times 24 + 161.42$

$$= 174.41$$

$= 174.5 \text{ cm}$ to the required level of

accuracy

Teacher note: an interesting comparison can be made if the two remaining possible outliers are eliminated. Will the line of best fit be steeper or less steep? Will the predicted Height therefore be taller or shorter?



Now the relationship $\text{Height} = 1.1451 \times \text{Footlength} + 145.5$, the height of the suspect would be calculated $\text{Height} = 1.1451 \times 24 + 145.5$

$$= 172.98$$

$= 173 \text{ cm}$ to the required level of

accuracy

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You now have a second estimate of the height of the person in the image, this time calculated from their foot length. Are the two estimates the same?

Using the trend line method above the prediction of height from belly-button height was 172.5 cm whereas the prediction from foot length was 174.5cm (reduced to 173cm if more suspected outliers were removed. These estimates are very close, suggesting that our prediction may well be reliable.

Task Four: Could the footprint belong to the person in the image?

- 7.** From your investigations, prepare a report to the manager of the forensic science unit. You will need to clearly state your conclusion about the question "Could the foot print belong to the person in the image?" You must provide evidence to support your conclusion.

In Task 1 we were able to predict the belly button height of the man in the image using a shorts length of 56cm. This prediction was around 98 – 100 cm. From this, in Task 2 we were able to make predictions of his height ie somewhere between 162 and 173 cm depending on the method used. In Task 3 a prediction of height using footlength was found to be around 173 cm, very close to the height predicted in Task 2. It is therefore possible for the footprint to belong to the man caught on the security camera image.

Extension

The Vitruvian Man and Golden Ratio

There are many relationships in nature similar to the one above. Arm span and height is another relationship that can be investigated using CensusAtSchool data.

The Vitruvian Man is one example that intrigues students of all ages. Who is he? Who made him? When? How is he connected to your earlier work?

Similarly, the golden ratio occurs in a wealth of situations, natural and man made.

This question is investigated in CaSMa12: The Golden Ratio.

Teacher Tips:

One way to proceed with this investigation would be to:

- develop estimates for the height of the person in the image based on the belly button height
- develop estimates of the height of the person based on the footprint length
- compare the two sets of estimates.



To find the belly button height of the person in the image measure the length of the shorts and the belly button height in the image. Then use ratio to find the real belly button height of the person if the shorts are 56 cm long.

$$\frac{\text{Belly button height in photograph}}{\text{length of shorts in photograph}} = \frac{\text{Belly button height in real life}}{56}$$

We can find the belly button height in real life:

$$\frac{\text{Belly button height in photograph}}{\text{length of shorts in photograph}} \times 56 = \text{Belly button height in real life}$$

To investigate Lucy's question students could:
 Draw an xy scatter plot of the two variables (height and belly button height) to determine the relationship. Excel can be used to draw a line of best fit and find its equation, if required.

Or

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Find the height divided by the belly button height for each row of data and average these.

You can expect this division to approximate to 1.6. ($\text{Height} = 1.6 \times \text{Belly button height}$).

In assessing student's work on this task, consideration of how well (if at all) the following points were included may be useful in differentiating between the levels of work presented.

Did the student:

- check the reliability of each of the data points in their sample?
- consider sampling variation by averaging the results from a number of like samples (this should be considered a high order inclusion)
- consider gender effects
- consider age effects
- choose the most appropriate sample

The activity could be broadened by changing Dan's first thought to:

"One of the team members, Dan, suggests that if they can determine the real-life length of something in the image from the security camera they may be able to make some progress.

After some investigation he identifies the brand and style of the board shorts being worn by the person. He also finds that they are made only in the following lengths 44 cm, 50 cm and 56 cm."